Dynamics of Forced Coastal-Trapped Disturbances

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LONG-TERM GOALS

The long-term goal of this project is to improve our ability to understand and predict meteorological conditions in the coastal marine atmospheric boundary layer.

OBJECTIVES

The objective of this project is to investigate the dynamics of coastal marine atmospheric boundary layer winds including the generation and propagation of coastal-trapped disturbances and their interaction with coastal orography and with orographically-modified ambient winds.

APPROACH

The approach taken in this project is to obtain analytical and numerical solutions of idealized mathematical models of the marine atmospheric boundary layer and to compare these solutions to observations and to results from more complex models.

WORK COMPLETED

Numerical and analytical models of the generation, propagation, and decay of linear and nonlinear coastal-trapped disturbances have been studied. Mesoscale simulations of the interaction of continuously stratified, hydraulically supercritical and transcritical flow with coastal orography have been carried out and analyzed, yielding new insight into the dynamics of coastal winds. Hydraulically transcritical model flows have been computed for comparison with observational data from the 1996 Coastal Waves Experiment along the California coast.

RESULTS

Mesoscale simulations of the interaction of hydraulically supercritical and transcritical flow with coastal orography revealed horizontal structure similar to that found previously in observations and in shallow-water models of supercritical and transcritical flow along a varying coastline (Burk et al,

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submitted 1998). However, a significant response in the stratified flow above the marine atmospheric boundary layer inversion was also observed in the simulations, a feature that is not represented in the simpler shallow-water case. Analysis of these simulations in terms of a shallow-water similarity theory implicated the vertical shear, rather than the stratification, as the dominant vertical trapping mechanism, giving new insight into previous shallow-water theories of this phenomenon. This work was conducted jointly with S. Burk and T. Haack at the Naval Research Laboratory, Monterey, using the mesoscale atmospheric model COAMPS.

Numerical investigations of the forcing, propagation, and decay of nonlinear coastal-trapped disturbances (CTDs) in a shallow-water model indicated that, in addition to the expected steepening of the leading edge of the disturbance wave, the nonlinear dynamics include enhanced dissipation when the marine layer thickness is small. Consequently, the propagating disturbance quickly evolves into a wave of elevation only. The alongshore structure of the freely-propagating wave of elevation is sensitive to variations in the time-dependent nature of the forcing. This work extends earlier results on linear CTDs in the shallow-water model (Rogerson and Samelson, 1995, Samelson and Rogerson, 1996).

Numerical solutions of a multi-layer primitive equation model with idealized topography, forced by fields derived from the NCEP Eta analysis during 9-12 June 1994, have been obtained to investigate the dynamics of the observed 10-11 June 1994 coastal-trapped disturbance. Preliminary results indicate the presence of both directly forced and propagating-wave components in the response, and suggest that leakage of low-level marine air over the coastal orography may limit the amplitude of the trapped response.

Numerical solutions of a nonlinear shallow-water model are being utilized to aid the dynamical interpretation of aircraft observations from the Coastal Waves 1996 field experiment in the vicinity of Cape Mendocino. The modeling study indicates that the flow downstream of the Cape is supercritical even when the upstream winds are only moderately strong, resulting in acceleration of the wind and a decrease in inversion height south of the Cape. The effect can be strong enough to cause flow separation in the vicinity of Shelter Cove, which is consistent with observations of weak winds nearshore within the Cove concomitant with very strong winds further offshore. This work is in collaboration with Kate Edwards and Clint Winant (SIO).

Work has continued on transcritical steady-state model flows and the interaction of coastal-trapped disturbances with the steady base flows (Rogerson, submitted 1998), and on the vertical structure of coastal-trapped disturbances in several idealized linear models (Samelson, 1998b).

In addition, this project has provided partial support for studies of the coastal ocean response to wind forcing (Samelson, 1997), the effect of spatial variations in turbulent mixing on the large-scale ocean circulation (Samelson, 1998a), and chaotic mixing in a quasi-geostrophic jet (Rogerson et al., 1998).

IMPACT/APPLICATIONS

Results from this theoretical and numerical modeling effort will contribute to the overall goal of improving weather prediction models through enhanced understanding of the dynamics that control coastal meteorological conditions.

TRANSITIONS

none

RELATED PROJECTS

This work is part of the ONR Coastal Meteorology ARI.

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